Vol. I. *No. IX.*

BULLETIN

OF THE

CHICAGO ACADEMY OF SCIENCE.

ON RHIZOCARPS

IN THE

ERIAN (DEVONIAN) PERIOD IN AMERICA.

BY SIR WILLIAM DAWSON, LL.D., F.R.S.

CHICAGO:

R. R. DONNELLEY & SONS, PRINTERS.

1886.

Vol. I. *No. IX.*

BULLETIN

OF THE

CHICAGO ACADEMY OF SCIENCE.

ON RHIZOCARPS

IN THE

ERIAN (DEVONIAN) PERIOD IN AMERICA.

BY SIR WILLIAM DAWSON, LL.D., F.R.S.

CHICAGO:
PRINTED FOR THE ACADEMY.
1886.

BULLETIN

OF THE

CHICAGO ACADEMY OF SCIENCES.

ON RHIZOCARPS IN THE ERIAN (DEVONIAN) PERIOD IN AMERICA.

BY SIR WILLIAM DAWSON, LL.D., F.R.S.

(READ BEFORE THE ACADEMY, MAY 11, 1886.)

The motive of the present paper is to notice certain specimens of the organs of fructification of cryptogams obtained from the Erian shales of Canada and Ohio, and from shale boulders in the Chicago boulder clay, and from the clay itself, and which have been prepared for microscopic examination by Mr. B. W. Thomas, F. R. M. S. of Chicago. I have, however, thought it best to sum up the present state of our knowledge of the subject, in connection with the descriptions of the new specimens recently studied. The subject may thus be treated under the following heads:

1. Recapitulation of the progress of discovery in relation to Sporangites and their allies.
2. Description of specimens recently studied.
3. Mode of occurrence of the specimens in relation to their origin.
4. Classification and description of species.
5. General remarks.

I.—RECAPITULATION.

My attention was first directed to the organisms referred to in this paper by the late Sir W. E. Logan in 1869. He had obtained from the Upper Erian Shale of Kettle Point, Lake Huron, specimens filled with minute circular discs to which he referred, in his report of 1863, as "microscopic orbicular bodies." Recognizing them to be macrospores, or spore-cases, I introduced them into the report on the Erian Flora which I was then preparing, and which was published in 1871, under the name *Sporangites Huronensis*.

In 1871, having occasion to write a communication to the American Journal of Science on the question then raised as to the share of spores and spore-cases in the accumulation of coal, these curious little bodies were again reviewed and were described in substance as follows:

"The oldest bed of spore-cases known to me is that at Kettle Point, Lake Huron. It is a bed of brown bituminous shale, burning with much flame, and under a lens is seen to be studded with flattened disc-like bodies, scarcely more than a hundredth of an inch in diameter, which under the microscope are found to be spore-cases (or macrospores) slightly papillate externally, (or more properly marked with dark pores,) and sometimes showing a point of attachment on one side and a slit more or less elongated and gaping on the other. When slices of the rock are made, its substance is seen to be filled with these bodies, which, viewed as transparent objects, appear yellow like amber, and show little structure, except that the walls can be distinguished from the internal cavity, which may sometimes be seen to enclose patches of granular matter. In the shale containing them, are also vast numbers of rounded, translucent granules, which may be escaped spores (microspores)."

The bed containing these spores at Kettle Point was stated in the reports of the Geological Survey of Canada, to be 12 to 14 feet in thickness, and besides these specimens it contained fossil plants referable to the species *Calamites inornatus* and *Lepidodendron primaevum*, and I not unnaturally supposed that the Sporangites might be the fruit of the latter plant. I also noticed their resemblance to the spore-cases of *L. corrugatum* of the lower Carboniferous, (a Lepidodendron allied to *L. primaevum*,) and to those from Brazil described by Carruthers under the name *Flemingites*, as well as to those described by Huxley from certain English coals, and to those of the Tasmanite or white coal of Australia. The bed at Kettle Point is shown to be marine by its holding *Spirophyton*, and shells of *Lingula*.

The subject did not again come under my notice till 1882, when Prof. Orton of Columbus, Ohio, sent me some specimens from the Erian shales of that state which on comparison seemed undistinguishable from *Sporangites Huronensis*. These shales have been described as to their Chemical and Geological relations, by Dr. T. Sterry Hunt, Am. Journal of Science, 1863, and by Dr. Newberry, in the Reports of the Geological Survey of Ohio, vol. I, 1863, and vol. III, 1878.

Prof. Orton read an interesting paper on these bodies, at the meeting of the American Association in Montreal, in which were some new and striking facts. One of these was the occurrence of such bodies throughout the black shales of Ohio, extending "from the Huron River on the shore of Lake Erie to the mouth of the Scioto in the Ohio valley, with an extent varying from ten to twenty miles in breadth," and estimated to be 350 feet in thickness.* Another was the absence of any traces of

*In a letter, received since the reading of this paper, Prof. Orton states that "borings in the Ohio black shale have penetrated it to a depth of 1800 feet without reaching the bottom." So that its whole thickness is probably much greater than stated in the text. Specimens of these borings kindly sent to me by Prof. Orton, are well filled with sporangites throughout the thickness of the shale as far as penetrated. —B. W. T.

Lepidodendroid cones, and the occurrence of filamentous vegetable matter, to which the Sporangites seemed to be in some cases attached in groups. Prof. Orton also noticed the absence of the trigonal form, which belongs to the spores of many Lepidodendra, though this is not a constant character.* In the discussion on Prof. Orton's paper, I admitted that the facts detailed by him shook my previous belief of the lycopodiaceous character of these bodies, and induced me to suspect, with Prof. Orton, that they might have belonged to some group of aquatic plants lower than the Lycopods.

In the same discussion, Prof. Williams, of Cornell University, mentioned that he had found similar bodies in the Hamilton shales of New York, and that they were associated with the curious pinnately leaved plant *Ptilophyton vanuxemii*, an observation to which I subsequently referred in discussing the affinities of this fossil, in a report on the Erian plants of Canada, published in 1882.† Prof. Williams was kind enough to send me specimens, in which, however, the round spore-case-like bodies were much less distinct than in the specimens from Ohio and Lake Huron. In the report above referred to I have also noticed the occurrence of rounded spore-like bodies in association with the stems of *Trochophyllum* of Lesquereux from the lower carboniferous of Pennsylvania, and of which specimens were submitted to me by Mr. Lacoe, of Pittston, and Prof. Lesquereux. *Trochophyllum* I regard as closely allied to or perhaps congeneric with *Ptilophyton*, and in the report already referred to I have argued that these plants were probably aquatic.

Still more recently Prof. J. M. Clarke, of Northampton, Mass., was so kind as to send me two fragments of rock containing *Sporangites* similar to those above mentioned—one from the Genessee shale of Canandaigua, N. Y., and another from the Corniferous Limestone. In the latter these bodies retain their globular form, though some are partially crushed in such a way as to show their membranous character. In slices prepared by Prof. Clarke the wall is seen to be thin and carbonaceous, with indications of a dense cellular structure, and some of the specimens show a projecting aperture or point of attachment at one side, giving them a somewhat pear-shaped appearance. The size of all these macrospores from the Erian of New York is nearly the same with that of Lake Huron specimens. Those found with *Trochophyllum* in the Lower Carboniferous are much larger.‡

No certain clue seemed to be afforded by all these observations as to the precise affinities of these widely distributed bodies; but this was furnished shortly after from an unexpected quarter. In March, 1883, Mr.

*On the source of the Bituminous matter of the black shales of Ohio. Proc. Am. Asso. 1882.

†Report on Erian Plants of Canada, Part II.

‡Prof. Clarke has described his specimens in the American Journal of Science, April, 1885, and has noticed some interesting points to be referred to in the sequel.

Orville Derby, of the Geological Survey of Brazil, sent me specimens found along with fronds of *Spirophyton* in the Erian of that country, which seemed to throw a new light on the whole subject. These I described and pointed out their connection with Sporangites at the meeting of the American Association, at Minneapolis, in 1883, and subsequently published my notes respecting them in its Proceedings and in the Canadian Record of Science. Mr. Derby's specimens recalled to remembrance certain fossils which had been sent to me several years ago by the late Prof. Hartt, and which, like Mr. Derby's specimens, occurred in beds holding *Spirophyton*, though these were at that time regarded as carboniferous. In a note propared for Prof. Hartt, but not, so far as I am aware, published, I had noticed these fossils as follows :

"*Sporangites*—Specimens from a shale at Rio Tapagos, above Itaituba.

"These are spore-cases, probably of a Lepidodendroid plant and resembling *S. Huronensis* of the Devonian of Canada. The specimens are labelled as Carboniferous, but the occurrence in them of abundant fronds of *Spirophyton* rather points to a Devonian date."

Mr. Derby's specimens contained *Spirophyton* and also minute rounded Sporangites like those obtained by Prof. Hartt. But they differed in showing the remarkable fact that these rounded bodies are enclosed in considerable numbers in spherical and oval sacs, the walls of which are composed of a tissue of hexagonal cells, and which resemble in every respect the involucres or spore-sacs of the little group of modern acrogens known as Rhizocarps, and living in shallow water. More especially they resemble the sporocarps of the genus *Salvinia*. This fact opened up an entirely new field of investigation, and I at once proceeded to compare the specimens with the fructification of modern Rhizocarps.

Mr. Derby's specimens are labelled as from Rio Trombetos and Rio Curua. They occur in two kinds of matrix. One is a thinly laminated sandy shale, tinged red with peroxide of iron, and with occasional ferruginous laminae. In this the spore-sacs are flattened and black, and show the structure of the walls under the microscope. The contained macrospores, when visible, appear as minute tubercles, or sometimes as depressions on the wall of the envelope, or more frequently as round light colored spots, according to their state of preservation. The other kind of matrix is a gray, dense shale in which the spore-sacs appear less flattened and usually destitute of carbonaceous matter.

The very numerous spore-sacs or sporocarps contained in these shales were so variable in size and form that they may have belonged to several species of plants, though on the other hand the differences might be attributed to age and state of preservation. They resolved themselves, however, into two leading types, which I named and described as *Sporangites Braziliensis* and *S. bilobata*, suggesting for them at the same

time the generic name *Protosalvinia*, in case the affinities which I think indicated by their structure should be fully established in the future. In the meantime I may adhere to the name *Sporangites*, which, though not technically correct, when applied to the individual macrospores, is sufficiently accurate when taken in connection with their occurrence in groups surrounded by cellular Sporocarps. Its priority and its use (since 1865) also give it claims to consideration. It will therefore be understood that when I use this term I refer to macrospores like those of the Lake Huron shale, as well as to Sporocarps containing macrospores, as in the Brazilian specimens. The equivalent term *Protosalvinia* I shall use as a prospective name to be applied to the whole plant so soon as this shall be known.

Since the publication of my paper on Rhizocarps in the Palaeozoic Period above referred to, I have received two papers from Mr. Edward Wethered, F. G. S., in one of which he describes spores of plants found in the Lower Limestone shales of the Forest of Dean, and in the other discusses more generally the structure and origin of Carboniferous Coal beds.* In both papers he refers to the occurrence in these coals and shales of organisms essentially similar to the Erian spores.

In the Bulletin of the Chicago Academy of Science, January, 1884, Dr. Johnson and Mr. Thomas, in their paper on the Microscopic Organisms of the Boulder Clay of Chicago and vicinity, notice *Sporangites Huronensis* as among these organisms, and have discovered them also in large numbers in the precipitate from Chicago city water supply. They refer them to the decomposition of the Erian shales, of which boulders filled with these organisms are of frequent occurrence in the Chicago clays. The Sporangites and their accompaniments in the boulder clay are also noticed in a paper by Dr. G. M. Dawson, in the Bulletin of the Chicago Academy, June, 1885.

Prof. Clarke has also described, in the American Journal of Science for April, 1885, the forms already alluded to and which he finds to consist of Macrospores enclosed in Sporocarps. He compares these with my *Sporangites Huronensis* and *Protosalvinia bilobata*, but I think it is likely that one of them at least is a distinct species.

I may add that in the Geological Magazine for 1875, Mr. Newton, F. G. S., of the Geological Survey, of England, published a description of the Tasmanite and Australian white coal, in which he shows that the organisms in these deposits are similar to my *Sporangites Huronensis*, and to the Macrospores previously described by Prof. Huxley, from the Better-bed coal. Mr. Newton does not seem to have been aware of my previous description of *Sporangites*, and proposes the name, *Tasmanites punctatus*, for the Australian form.

* Cotteswold Naturalists' Field Club, 1884. Journal of Royal Microscopical Society, 1885.

Mr. R. Kidston, F. G. S., has recently been engaged in the examination of the spores and sporangia contained in Devonian and Carboniferous deposits in Scotland, and some of which, as he informs me, are similar to those referred to in this paper; but I have not yet seen his published results.

To the kindness of Mr. Thomas I am indebted for a large series of microscopic preparations of these fossils, and of others in the Bedford shale of Ohio, prepared from specimens sent to him by Prof. Orton, the results of the microscopic examination of which I propose to notice, and to inquire as to the inferences which are now warranted respecting the affinities of these organisms.

II.—DESCRIPTION OF THE SPECIMENS.

The typical macrospores from the Erian shales are perfectly circular in outline, and in the flattened state appear as discs with rounded edges, their ordinary diameter being from 1-75th to 1-100th of an inch, though they vary considerably in size. This, however, I do not regard as an essential character. The edges, as seen in profile, are smooth, but the flat surface often presents minute dark spots, which at first, I mistook for papillæ; but now agree with Mr. Thomas in recognizing them as minute pores traversing the wall of the disc, and similar to those which Mr. Newton has described in Tasmanite, and which Mr. Wethered has also recognized in the similar spores of the Forest of Dean shales. The walls also sometimes show faint indications of concentric lamination, as if they had been thickened by successive deposits.

As seen by transmitted light, and either in front or in profile, the discs are of a rich amber color, translucent and structureless, except the pores above referred to. The walls are somewhat thick, or from $\frac{1}{10}$th to $\frac{1}{20}$th the diameter of the disc in thickness. They never exhibit the triradiate marking seen in spores of Lycopods, nor any definite point of attachment, though they sometimes show a minute elongated spot which may be of this nature, and they are occasionally seen to have opened by slits on the edge or front, where there would seem to have been a natural line of dehiscence. The interior is usually quite vacant or structureless, but in some cases there are curved internal markings which may indicate a shrunken lining membrane, or the remains of a prothallus or embryo. Occasionally a fine granular substance appears in the interior, possibly remains of microspores.

The discs are usually detached and destitute of any envelope, but usually fragments of flocculent cellular matter are associated with them, and in one specimen from the corniferous limestone of Ohio, in Mr. Thomas' collection, I have found a group of eight or more discs partly enclosed in a cellular sac-like membrane of similar character to that enclosing the Brazilian specimens already referred to.

The characters of all the specimens are essentially similar, and there is a remarkable absence of other organisms in the shale. In one instance only, I have observed a somewhat smaller round body with a dark centre or nucleus, and a wide translucent margin, marked by a slight granulation. Even this, however, may indicate nothing more than a different state of preservation.

It is proper to observe here that the wall or enclosing sac of these macrospores must have been of very dense consistency, and now appears as a highly bituminous substance; in this agreeing with that of the spores of Lycopods, and like them, having been when recent of a highly carbonaceous and hydrogenous quality, very combustible and readily admitting of change into bituminous matter. In the paper already referred to, on spore-cases in coals, I nave noticed that the relative composition of lycopodium and cellulose is as follows:

Cellulose C_{24} H_{20} O_{20}

Lycopodium C_{42} H $19\frac{4}{12}$ N O 5 $\frac{6}{10}$.

Thus, such spores are admirably suited for the production of highly carbonaceous or bituminous coals, etc.

Nothing is more remarkable in connection with these bodies than their uniformity of structure and form over so great areas and throughout so great thickness of rock, and the absence of any other kind of spore-case. This is more especially noteworthy in contrast with the coarse coals and bituminous shales of the carboniferous, which usually contain a great variety of spores and sporangia, indicating the presence of many species of acrogenous plants, while the Erian shales on the contrary indicate the almost exclusive predominance of one form. This contrast is well seen in the Bedford shales overlying these beds, and I believe Lower Carboniferous.* Specimens of these have been kindly communicated to me by Prof. Orton, and have been prepared by Mr. Thomas. In these we see the familiar carboniferous spores with triradiate markings called *Triletes* by Reinsch, and which are similar to those of Lycopodiaceous plants. Still more abundant are those spinous and hooked spores or sporangia, to which the names *Sporocarpon*, *Zygosporites* and *Traquaria* have been given, and some of which Williamson has shown to be spores of Lycopodiaceous plants.†

The true "Sporangites" on the contrary are round and smooth, with thick bituminous walls, which are punctured with minute transverse pores. In these respects, as already stated, they closely resemble the bodies found in the Australian white coal and Tasmanite. The precise geological age of this material is not known with certainty, but it is believed to be Palaeozoic.

* According to Newberry, lower part of Waverly group.

† *Traquaria* is to be distinguished from the calcareous bodies found in the corniferous limestone of Kelly's Island, which I have described in the Canadian Naturalist as *Saccamina eriana*, and believe to be Foraminiferal tests. See Dr. Williamson's papers in transactions of Royal Society of London.

III.—MODE OF OCCURRENCE OF SPORANGITES, AND ITS BEARING ON THEIR ORIGIN.

Under this head we may note first the great abundance and wide distribution of these bodies. The horizontal range of the bed at Kettle Point is not certainly known, but it is merely a northern outlier of the great belt of Erian shales referred to by Prof. Orton, and which extends, with a breadth of ten to twenty miles, and of great thickness, across the State of Ohio, for nearly 200 miles. This Ohio black shale, which lies at the top of the Erian or the base of the Carboniferous, though probably mainly of Erian age, appears to abound throughout in these organisms and in some beds to be replete with them. In like manner, in Brazil, according to Mr. Derby, these organisms are distributed over a wide area and throughout a great thickness of shale holding *Spirophyton*, and apparently belonging to the Upper Erian. The recurrence of similar forms in the Tasmanite and white coal of Tasmania and Australia is another important fact of distribution. To this we may add the appearance of these macrospores in coals and shales of the Carboniferous period, though there in association with other forms.

It is also to be observed that the Erian shales, and the Forest of Dean beds described by Wethered, are marine, as shown by their contained fossils; and though I have no certain information as to the Tasmanite and Australian white coal, they would seem, from the description of Milligan, to occur in distinctly aqueous, possibly estuarine, deposits. Wethered has shown that the discs described by Huxley and Newton in the Better-bed coal occur in the earthy or fragmentary layers as distinguished from the pure coal. Those occurring in cannel coal are in the same case, so that the general mode of occurrence implies water-driftage, since in the case of bodies so large and dense, wind-driftage to great distances would be impossible.

These facts, taken in connection with the differences between these macrospores and those of any known land plant of the Palaeozoic, would lead to the inference that they belonged to aquatic plants, and these vastly abundant in the waters of the Erian and Carboniferous periods.

It is still further to be observed that they are not, in the Erian beds, accompanied with any remains of woody or scalariform tissues such as might be expected in connection with the debris of terrestrial acrogens, and that, on the other hand, we find them enclosed in cellular sporocarps, though in the majority of cases these have been removed by dehiscence or decay.

These considerations, I think, all point to the probability which I have suggested in my previous paper on this subject, that we have in these objects the organs of fructification of plants belonging to the order *Rhizocarpeæ*, or akin to it. The comparisons which I have instituted with the

sporocarps and macrospores of these plants confirm this suggestion. Of the modern species which I have had an opportunity to examine, *Salvinia natans* of Europe perhaps presents the closest resemblance. In this plant groups of round cellular sporocarps appear on the surface of the floating fronds. They are about a line in diameter when mature, and are of two kinds, one containing macrospores, the other microspores or antheridia. The first, when mature, hold a number of closely packed globular or oval sporangia of loose cellular tissue attached to a central placenta. Each of these sporangia contains a single macrospore, perfectly globular and smooth, with a dense outer membrane (exhibiting traces of lamination, and showing within an irregularly vacuolated or cellular structure, probably a prothallus). I can not detect in it the peculiar pores which appear in the fossil specimens. Each macrospore is about one-seventieth of an inch in diameter when mature. The sporocarps of the microspores contain a vastly greater number of minute sporangia, about one two-hundredths of an inch in diameter. These contain disc-like antheridia, or microspores of very minute size.

The discs from Kettle Point and from the Ohio black shale, and from the shale boulders of the Chicago clays, are similar to the macrospores of *Salvinia*, except that they have a thicker wall and are a little less in diameter, being about one-eightieth of an inch. The Brazilian sporocarps are considerably larger than those of the modern Salvinia, and the macrospores approach in size to those of the modern species, being one-seventy-fifth of an inch in diameter. They also seem, like the modern species, to have thinner walls than those from Canada, Ohio and Chicago. No distinct indication has been observed in the fossil species of the inner Sporangium of *Salvinia*. Possibly it was altogether absent, but more probably it is not preserved as a distinct structure.

With reference to the microspores of Salvinia, it is to be observed that the sporocarps, and the contained spores or antheridia, are very delicate and destitute of the dense outer wall of the macrospores. Hence such parts are little likely to have been preserved in a fossil state; and in the Erian shales, if present, they probably appear merely as flocculent carbonaceous matter not distinctly marked, or as minute granules not well defined, of which there are great quantities in some of the shales.

The vegetation appertaining to the Sporangites has not been distinctly recognized. I have, however, found in one of the Brazilian specimens two sporocarps attached to what seems a fragment of a cellular frond, and numerous specimens of the supposed Algæ, named *Spirophyton*, are found in the shales, but there is no evidence of any connection of this plant with the Protosalvinia.

Modern Rhizocarps present considerable differences as to their vegetative parts. Some, like *Pilularia*, have simple linear leaves; others, like

Marsilea, have leaves in verticils and cuneate in form; while others, like *Azolla* and *Salvinia*, have frondose leaves, more or less pinnate in their arrangement. The first type presents little that is characteristic, but there are in the Erian sandstones and shales great quantities of filamentous and linear objects which it has been impossible to refer to any genus, and which might have belonged to plants of the type of *Pilularia*. It is quite possible, also, that such plants as *Psilophyton glabrum* and *Cordaites augustifolia*, of which the fructification is quite unknown, may have been allied to Rhizocarps. With regard to the verticillate type, we are at once reminded of *Sphenophyllum*, which many palæo-botanists have referred to the *Marsiliaceæ*, though like other Palæozoic Acrogens, it presents complexities not seen in its modern representatives, *S. primævum* of Lesquereux is found in the Hudson River group, and my *S. antiquum* in the Middle Erian. Besides these, there are in the Silurian and Erian beds plants with verticillate leaves which have been placed with the Annulariæ, but which may have differed from them in fructification. *Annularia laxa*, of the Erian, and *Protannularia Harknessii*, of the Silurio-Cambrian, may be given as examples, and must have been aquatic plants, probably allied to Rhizocarps. It is deserving of notice, also, that the two best known species of Psilophyton (*P. princeps* and *P. robustius*), while allied to Lycopods by the structure of the stem and such rudimentary foliage as they possess, are also allied, by the form of their fructification, to the Rhizocarps, and not to ferns, as some palæo-botanists have incorrectly supposed.

The curious plants known as *Arthrostigma*, seem also to have been allied to Psilophyton in their fruit, though bearing it in spikes instead of as separate sporocarps.*

I would also here direct attention to those pinnate leaves from the Erian and Carboniferous, which I have named *Ptilophyton*, and to those from the Carboniferous, which Lesquereux has named *Trochophyllum*. I have fully discussed the structure of these in my Report of 1882 on the Erian Plants of Canada, and may here merely state that I have shown that they were aquatic plants, probably bearing sporocarps attached to their stems somewhat in the manner of *Azolla*.

The whole of this evidence, I think, goes to show that in the Erian period there were vast quantities of aquatic plants allied to the modern Rhizocarps, and that the so-called Sporangites referred to in this paper were probably the drifted sporocarps and macrospores of some of these plants or of plants allied to them in structure and habit, of which the vegetative organs have perished. I have shown that in the Erian period there were vast swampy flats covered with *Psilophyton*, and in similar submerged tracts near to the sea the *Protosalvinia* may have filled the waters and have given off the vast multitudes of Macrospores which drifted by currents have settled in the mud of the black shales.

* Report on Erian Plants of Canada, Part II, 1882.

III.—CLASSIFICATION OF SPORANGITES.

It is, of course, very unsatisfactory to give names to mere fragments of plants, yet it seems very desirable to have some means of arranging them. With respect to the organisms of the present paper, which were originally called by me *Sporangites*, under the supposition that they were Sporangia rather than Spores, this name has so far been vindicated by the discovery of the spore-cases belonging to them, so that I think it may still be retained as a provisional name; but I would designate the whole as *Protosalviniæ*, meaning thereby plants with Rhizocarpean affinities, though possibly when better understood belonging to different genera. We may under these names speak of their detached discs as macrospores and of their cellular envelopes as sporocarps. The following may be recognized as distinct forms.

1.—*Protosalvinia Huronensis*, Dawson, Syn., Sporangites Huronensis, Report on Erian Flora of Canada, 1871.—Macrospores in the form of discs or globes, smooth and thick-walled, the walls penetrated by minute radiating pores. Diameter about $\frac{1}{100}$th of an inch or a little more. When in situ several macrospores are contained in a thin cellular sporocarp, probably globular in form. From the Upper Erian, and perhaps Lower Carboniferous shales of Kettle Point, Lake Huron, of various places in the State of Ohio, and in the shale boulders of the boulder clay of Chicago and vicinity. First collected at Kettle Point by Sir W. E. Logan, and in Ohio by Prof. Edward Orton, and at Chicago by Dr. H. A. Johnson and Mr. B. W. Thomas, also in New York by Prof. J. M. Clarke.

The macrospores collected by Mr. Thomas from the Chicago clays and shales conform closely to those of Kettle Point, and probably belong to the same species. Some of them are thicker in the outer wall, and show the pores much more distinctly. These have been called by Mr. Thomas *S. Chicagoensis*, and may be regarded as a varietal form. Specimens isolated from the shale and mounted dry, show what seems to have been the hilum or scar of attachment better than those in balsam.

Sections of the Kettle Point shale show, in addition to the Macrospores, wider and thinner shreds of vegetable matter, which I am inclined to suppose to be remains of the Sporocarps.

2.—*Protosalvinia* (*Sporangites*) *Braziliensis*, Dawson, Can. Rec. of Sci., 1883.—Macrospores, round, smooth, a little longer than those of the last species, or about $\frac{1}{75}$th of an inch in diameter, enclosed in round, oval or slightly reniform sporocarps, each containing from four to twenty-four macrospores. Longest diameter of sporocarps three to six millimeters. Structure of wall of sporocarps hexagonal cellular. Some sporocarps show no macrospores, and may possibly contain microspores. The specimens are from the Erian of Brazil. Discovered by Mr. Orville Derby. The formation, according to Mr. Derby, consists of black shales below, about

300 feet thick, and containing the fucoid known as Spirophyton, and probably decomposed vegetable matter. Above this is chocolate and reddish shale in which the well preserved specimens of *Protosalvinia* occur. These beds are very widely distributed and abound in *Protosalvinia* and *Spirophyton.*

3.—*Protosalvinia* (*Sporangites*) *bilobata*, Dawson, Can. Rec. of Science, 1883.—Sporocarps, oval or reniform, three millimeters to six millimeters in diameter, each showing two rounded prominences at the ends, with a depression in the middle, and sometimes a raised neck or isthmus at one side connecting the prominences. Structure of sporocarp cellular. Some of the specimens indicate that each prominence or tubercle contained several macrospores. At first sight it would be easy to mistake these bodies for valves of *Beyrichia.*

Found in the same formations with the last species, though in so far as the specimens indicate, not precisely in the same beds. Collected by Mr. Derby.

4.—*Protosalvinia Clarkei*, Dawson, P. bilobata, Clarke, Am. Jl. of Science.—Macrospores $\frac{2}{3}$ to 1 millimeter in diameter. One, two or three contained in each sporocarp, which is cellular. The macrospores have very thick walls with radiating tortuous tubes. Unless this structure is a result of mineral crystallization, these macrospores must have had very thick walls and must have resembled in structure the thickened cells of stone fruits and of the core of the pear, or the tests of the Silurian and Erian seeds known as *Pachytheca*, though on a smaller scale.

It is to be observed that bodies similar to these occur in the Boghead earthy bitumen and have been described by Credner.

I have found similar bodies in the so-called "Stellar coal" of the coal district of Pictou, Nova Scotia, some layers of which are filled with them. They occur in groups or patches, which seem to be enclosed in a smooth and thin membrane or sporocarp. It is quite likely that these bodies are generically distinct from *Protosalvinia.*

5.—*Protosalvinia punctata*, Newton, Geol. Mag. N. S. Dec. 2, vol. II. Mr. Newton has named the discs found in the white coal and Tasmanite, *Tasmanites*, the species being *Tasmanites punctatus*, but as my name Sporangites had priority, I do not think it necessary to adopt this term, though there can be little doubt that these organisms are of similar character. The same remark may be made with reference to the bodies described by Huxley and Newton as occurring in the Better-bed coal.

V.—GENERAL REMARKS.

It may be well to mention here the various characters of pyroschists or bituminous shales of different ages, as they have come under my notice.

The Utica shale of Collingwood, Ontario, which has been used for the distillation of coal oil, shows under the microscope only flocculent matter and slender spicules, and its bitumen seems to have been derived from the disintegration of algæ and zoophytes.

A specimen of inflammable shale from the Trenton of Minnesota, prepared by Mr. Thomas, shows similar shreds of organic matter without any macrospores.

Bituminous shales associated with a small layer of coal in the middle Erian of Gaspe, show great quantities of shreds of epidermal tissue and fragments of the chitinous crusts of Eurypterids, but no distinct macrospores.

The richly bituminous shales of the Lower Carboniferous of Albert county, New Brunswick, which have furnished the material of the Albertite or hardened bitumen of that district, have not afforded any macrospores in the specimens I have been able to examine, but are filled with shreds apparently of vegetable matter in a much disintegrated state.

The Bedford shales of Ohio contain, in addition to fragments of epidermal and woody and vascular tissue, many forms of macrospores quite distinct from those of the underlying Erian shales. A similar remark may be made as to many varieties of coarse coal, cannel coal and bituminous shale of the coal measures, in which many forms of macrospores and sporangia may be found mixed with shreds of the more durable tissues, and especially of the epidermal tissue of various kinds of plants. Dr. Newberry and Mr. Julian have described in the Annals of the N. Z. Academy of Science, 1883, a number of specimens of bituminous shales not containing Sporangites, and Dr. Newberry refers the bituminous matter to the decomposition of algæ, or in some cases to that of miscellaneous vegetable débris from the land, a conclusion which he has applied also to the cannel coals.

From these facts it would appear that the presence of Rhizocarpean macrospores is not a necessary condition of the formation of bituminous shales, earthy bitumens or coals. Yet it seems certain that the macrospores are the cause of the highly bituminous character of the shales which are charged with them. On the other hand, many highly bituminous shales, such as, for instance, some beds of the Utica shale and the Lower Carboniferous shales of Albert county, New Brunswick, depend for their inflammable matter on microscopic débris of an entirely different character.

In point of fact* any kind of epidermal or dense cortical tissue has chemical properties not very dissimilar from those of the tests of macrospores; and such tissues have, as I have elsewhere shown,† been mainly instrumental in the production of coal, in some layers of which, however, macrospores and sporangia occur in large quantity. In regard to strictly marine shales, while it is probable or suggested by Newberry, that algæ may have furnished the material of much of the bituminous matter, I confess I am inclined to attach some importance in this respect to the corneous substance of Graptolites and other Zoophytes, which is nearer in composition to corky and epidermal matter.

In a botanical point of view the facts stated in this paper show that in the Erian, and probably also in the Carboniferous age, the type of plants now represented by the Rhizocarps was very largely developed, and that the macrospores of these plants were produced in such abundance as to charge great thicknesses of shales over very large areas with these bodies, which, owing to the density and indestructible character of the outer test, have resisted decomposition and remain unmineralized in the mass, giving to it the same highly combustible character which would result from the mixture of a like amount of Lycopodium spores with similar sediment.

*See my paper on Spore-cases in Coal. American Journal of Science, 1871.

†Journal of Geol. Society of London, 1865, and American Journal of Science, 1871. Also Acadian Geology, 1878.

Description of Figures.

Figure 1. Protosalvinia (sporangites) Braziliensis, sporocarps and spores, nat. size. 1a, 1b, same enlarged; 1c, cellular tissue of sporocarp much magnified.

Figure 2. P. (sp.) bilobata, nat. size.

Figure 3. Salvinia natans, modern, sporocarps, nat. size.

3a. Sporocarp with macrospores enlarged.

3b. Macrospores with sporangium, × 80.

3c. Sporangium with microspores × 80.

3d. Wall showing lamination.

Figure 4. P. (sp.) Huronensis, macrospore × 80, showing pores, 4a, 4b, portions of wall more magnified.

Figure 5. P. (sp.) Huronensis, showing hilum and internal granular matter × 80.

Figure 6. P. (sp.) Huronensis with thickened wall × 80, 6a, nat. size.

Figure 7. P. (sp.) Huronensis, group with remains of sporocarp; Corniferous Limestone. × 40. 7a cellular tissue of sporocarp highly magnified.

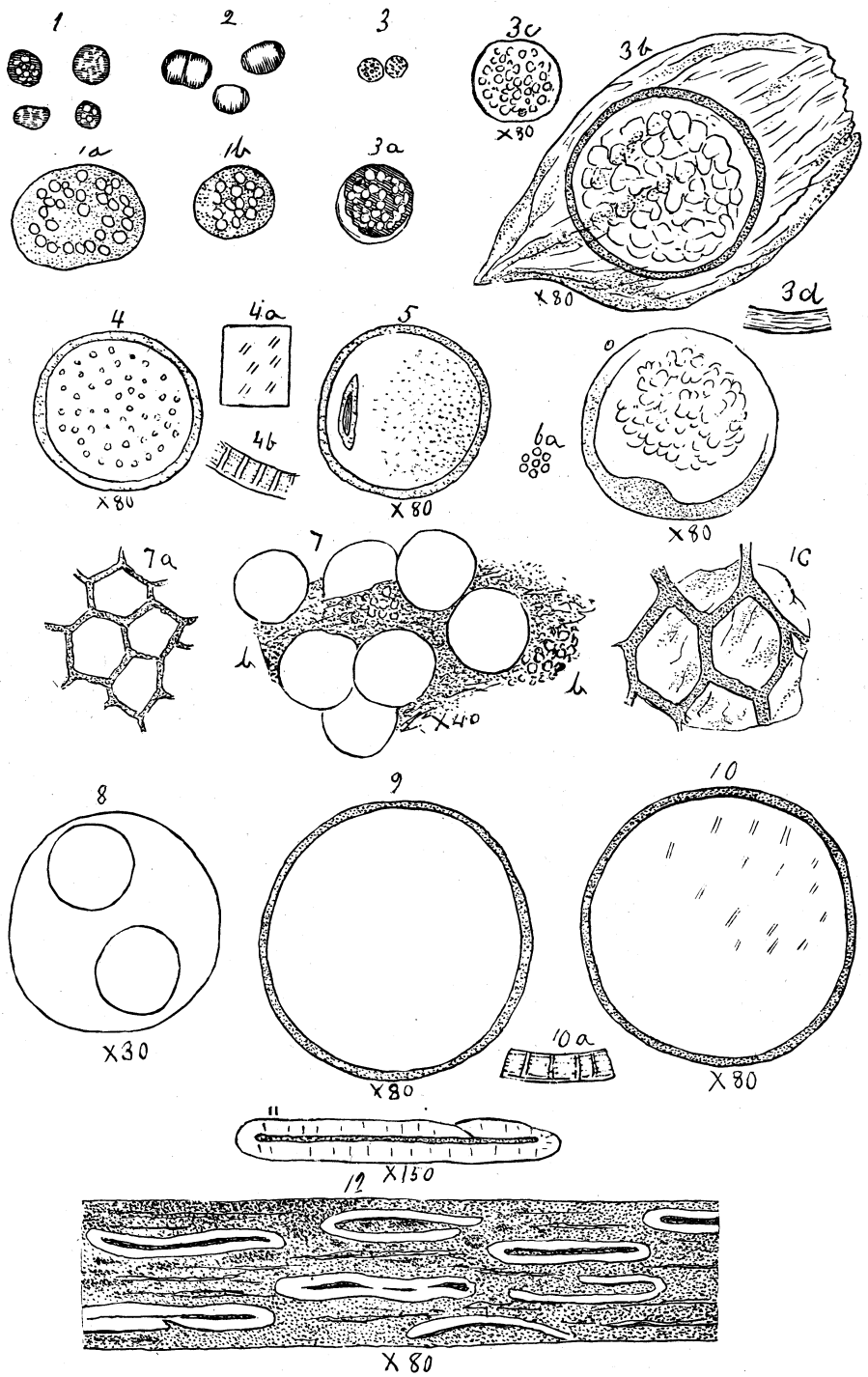
Figure 8. P. Braziliensis, sporocarp and 2 macrospores, outline, × 30.

Figure 9. P. Braziliensis, Macrospore ×.

Figure 10. P. (Tasminites) punctatus, × 80, showing pores; 10a, wall highly magnified, showing pores.

Figure 11. P. (sp.) Huronensis, Section × 150.

Figure 12. Shale from Kettle Point, showing flattened macrospores and remains of sporocarps, × 80.


1
2
3
3c
3b
×80
1a
1b
3a
3d
4
4a
5
6
×80
4b
×80
6a
×80
7a
7
×40
1c
8
9
10
×30
×80
10a
×80
11
12 ×150
×80